Biomass co-firing tests on a 5 MW_{th} experimental rig

Enel Produzione

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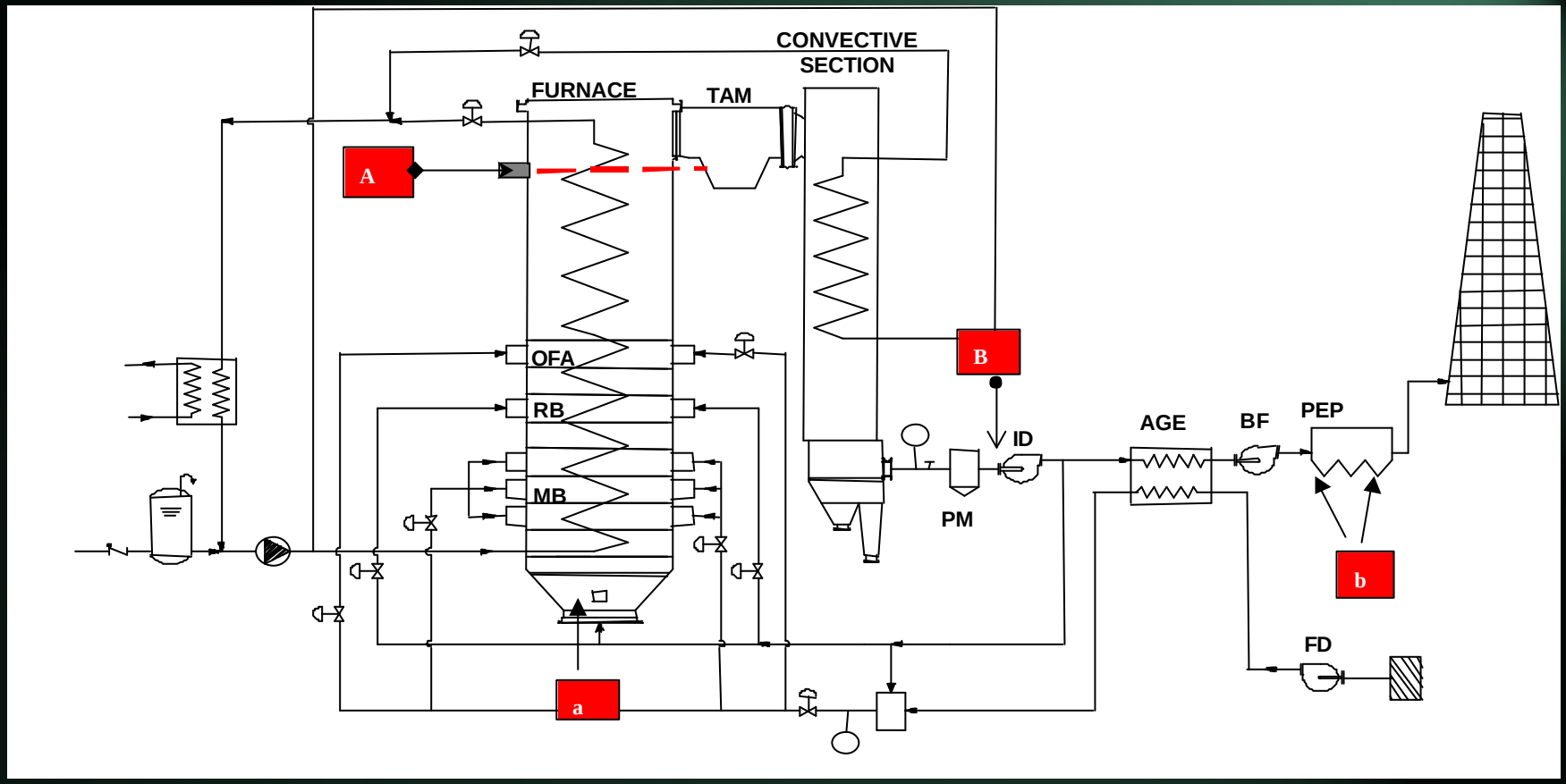
Biomass as fuel for power production

- the use of biomass in order to produce power closes perfectly the carbon cycle, but which are the problems connected to such type of fuel
- Many places on the earth are covered by trees and shrubs well adapted to the area where they grow but how much biomass can be produced in that area and how much power can be obtained. It is difficult to think to biomass as total substitute of fossil fuels
- In order to use biomass as co-fuel in conventional boilers the open question are: which consequences on combustion arise from the use of biomass, which on the boiler, which on the emissions and in general on the environment. Testing biomasses on an experimental rig is of great interest

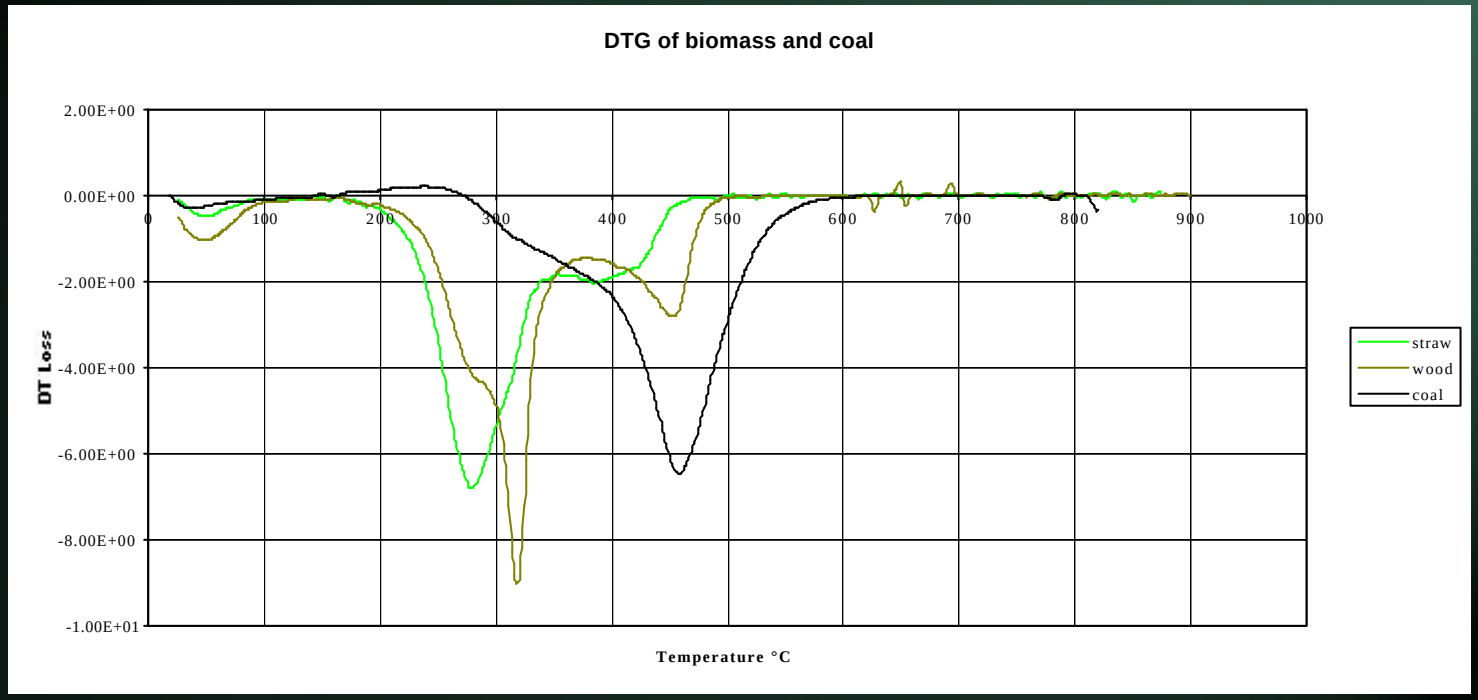
S. Gilla Simulator



Internal view of the combustion chamber

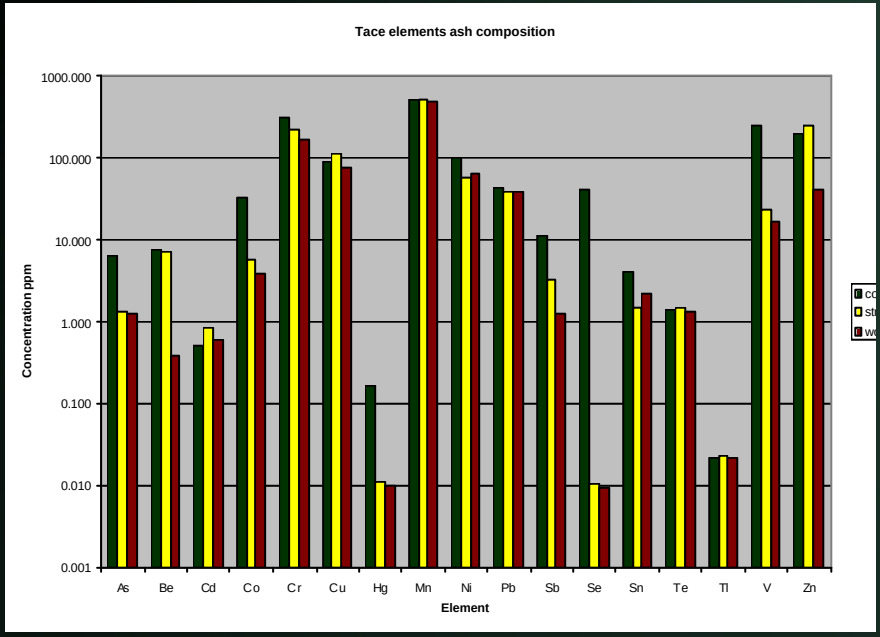
Comparison of biomass and coal

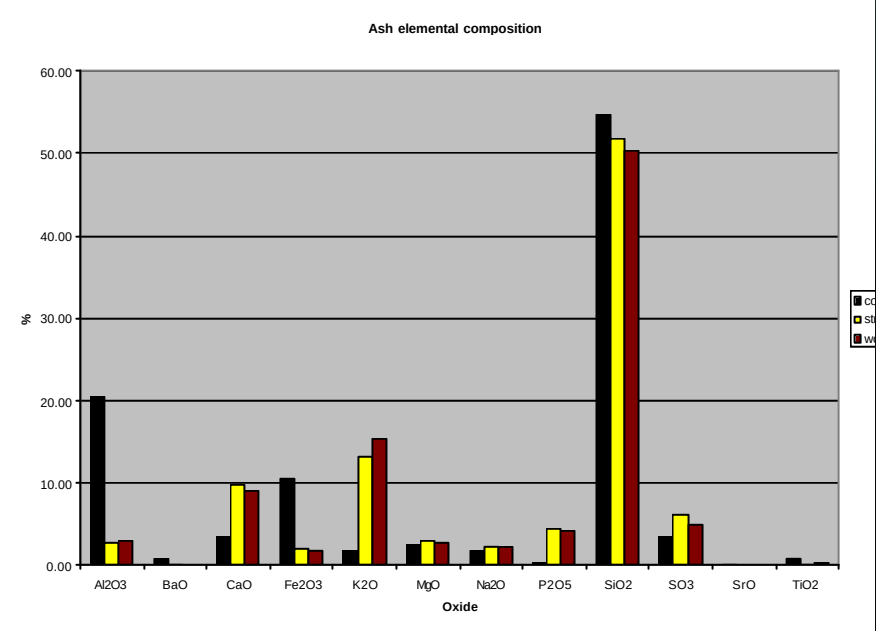
Coal is a biomass with some millions year of life,
Biomass burns more easily than coal



Comparison of biomass and coal

Ash from biomass is cleaner than that from coal





Comparison of biomasses

We analised some hundreds of biomasses in order to understand their suitability in conventional plants, the most important criteria are

- their availability and cost
- the environmental compatibility and with the boiler components,
- In order to compare the composition of different biomasses it is useful to make a PCA on a data base

Principal Components Analysis

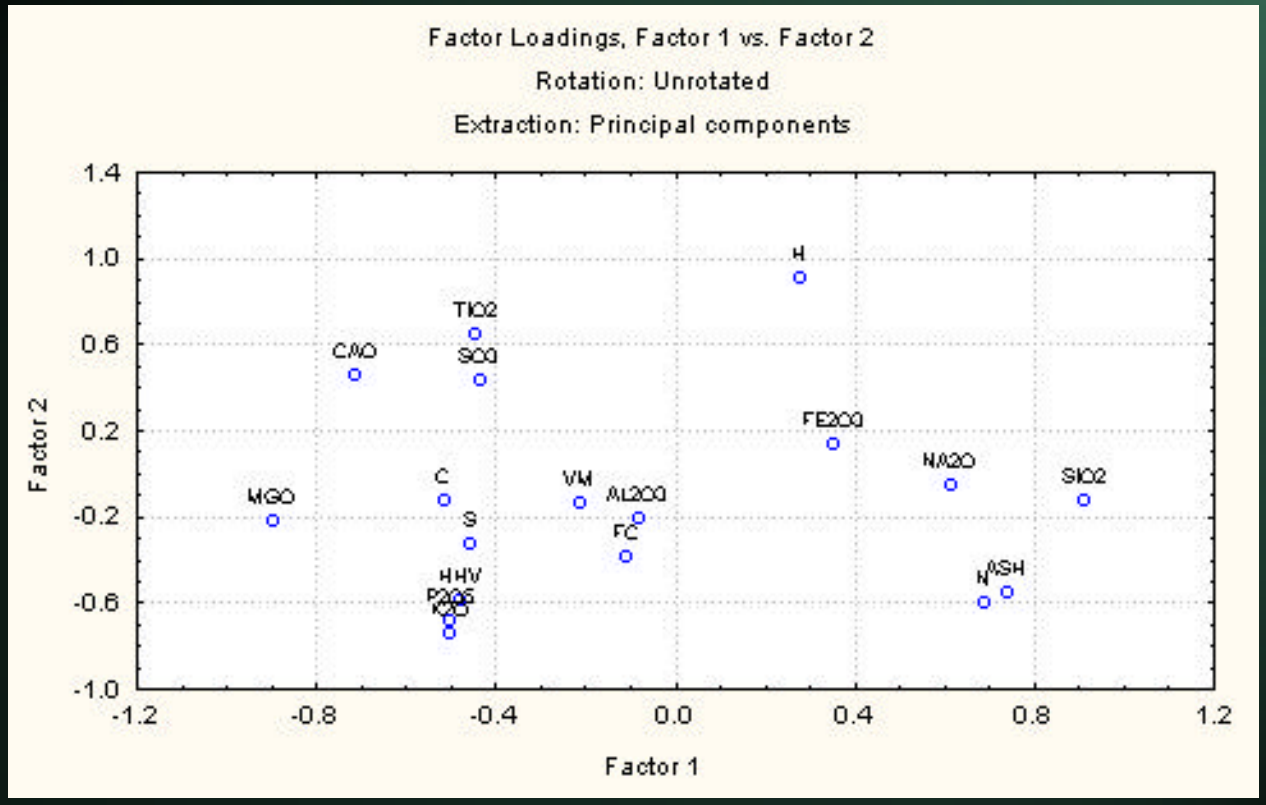
The Principal Components Analysis (PCA) is a statistical technique in the group of pattern recognition which allows to estimate the relative importance of variables and their relationships, this technique allows to reduce the dimensions of a problem excluding the correlate information.

Principal Components Analysyis

- The principal components are obtained as linear combination of the original variables.
- The relative importance of the original variables on the principal components graph is expressed as loading (cosine of the angle from the original variable and the principal component)
- The variables are positioned in the new space depending on the value of loadings
- The experimental points in the new space are positioned by their scores (projections on the new co-ordinate system)

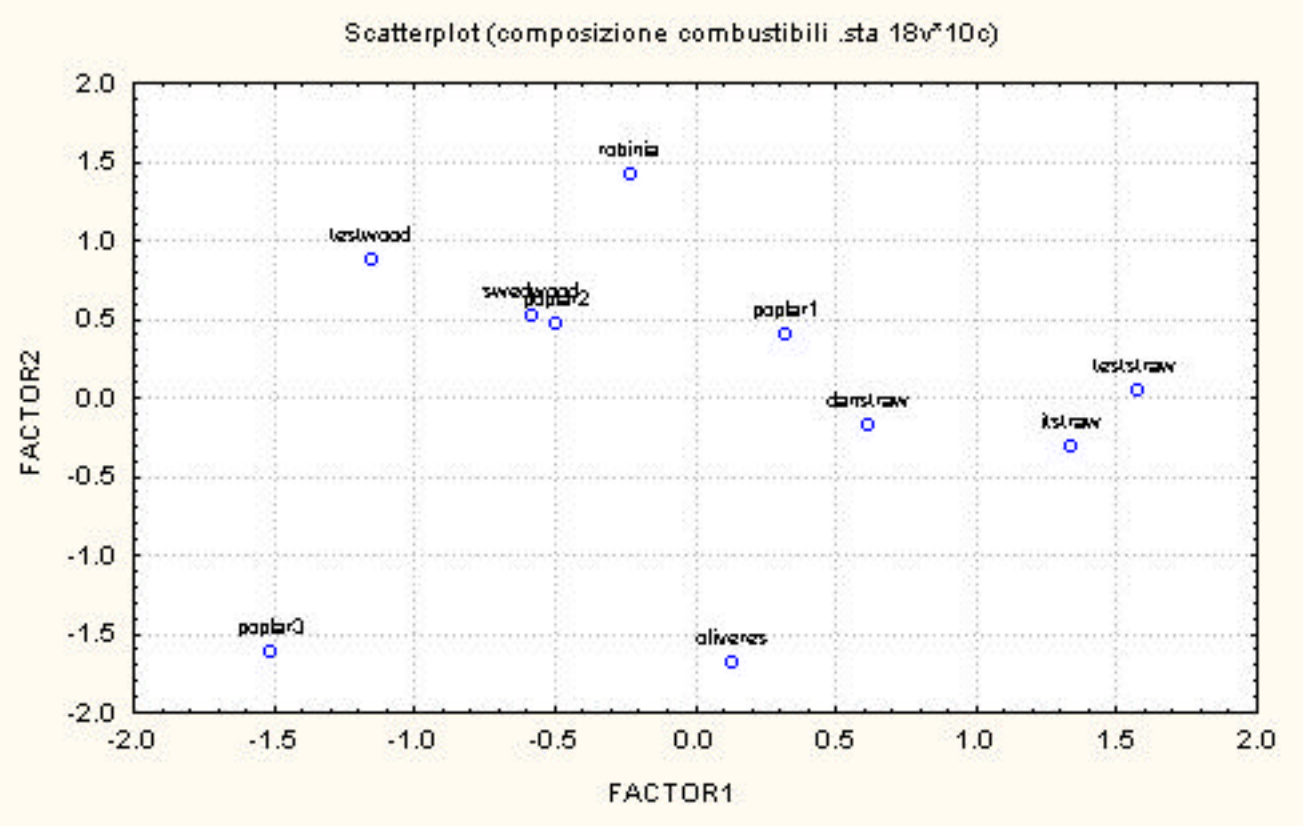
Comparison of biomasses

Plot of loadings of a 20 x 10 Data base including the fuels used at the S. Gilla Experimental rig



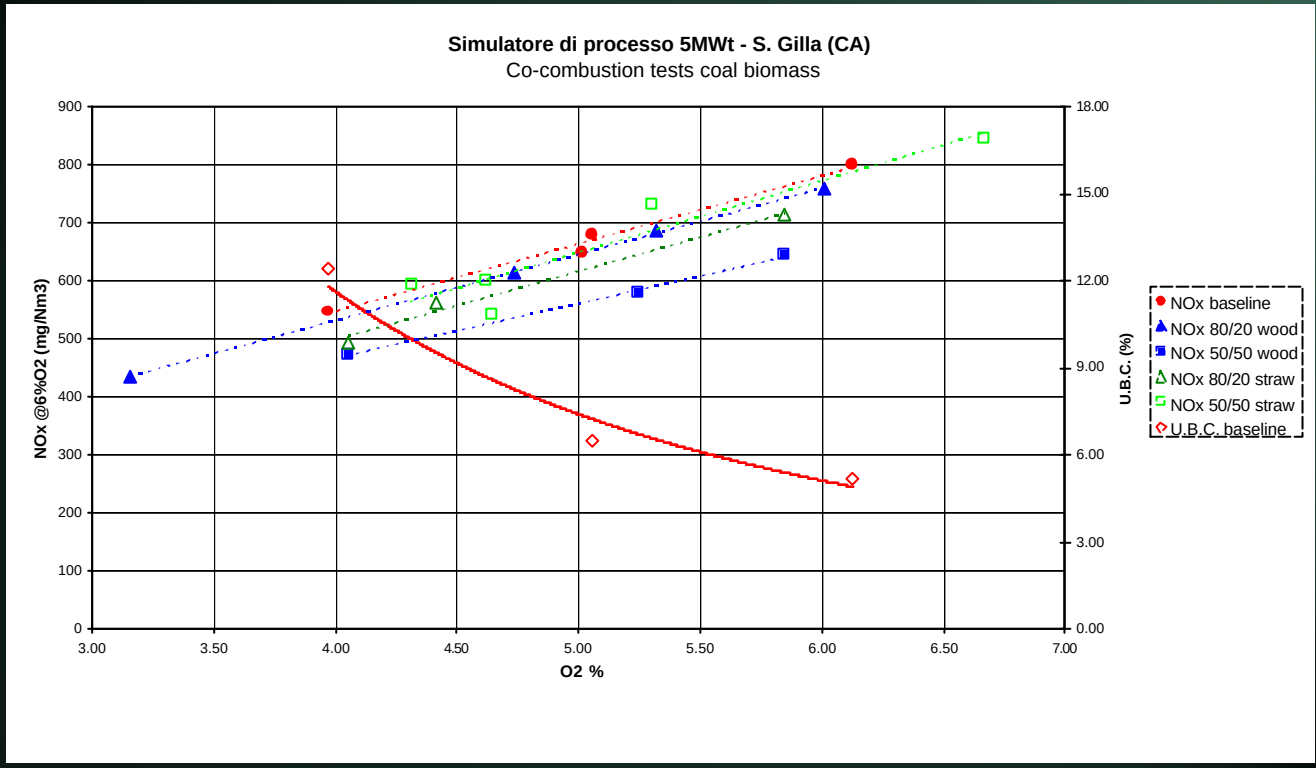
Comparison of biomasses

Plot of scores of a 20 x 10 Data base including the fuels used at the S. Gilla Experimental rig



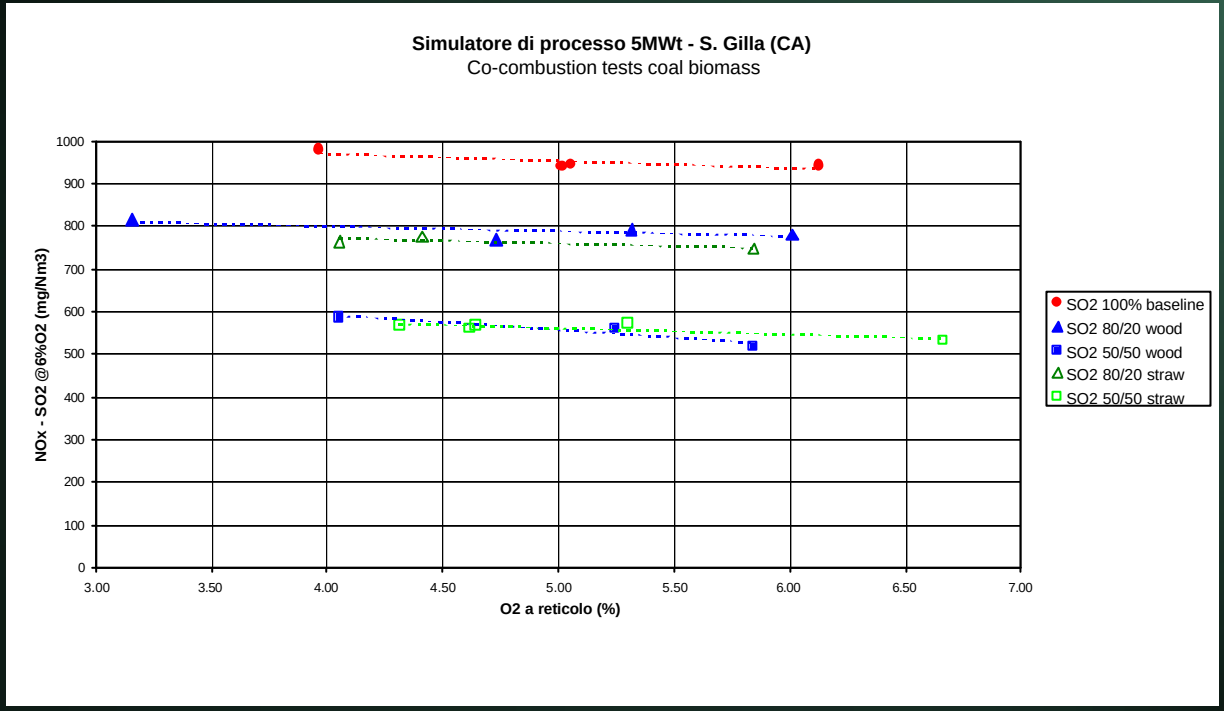
Co-combustion coal biomass

Co-combustion coal-biomass. Tests made at 4 MW of thermal input. The lower concentration of N in the fuel leads to a lower production of NOx with wood



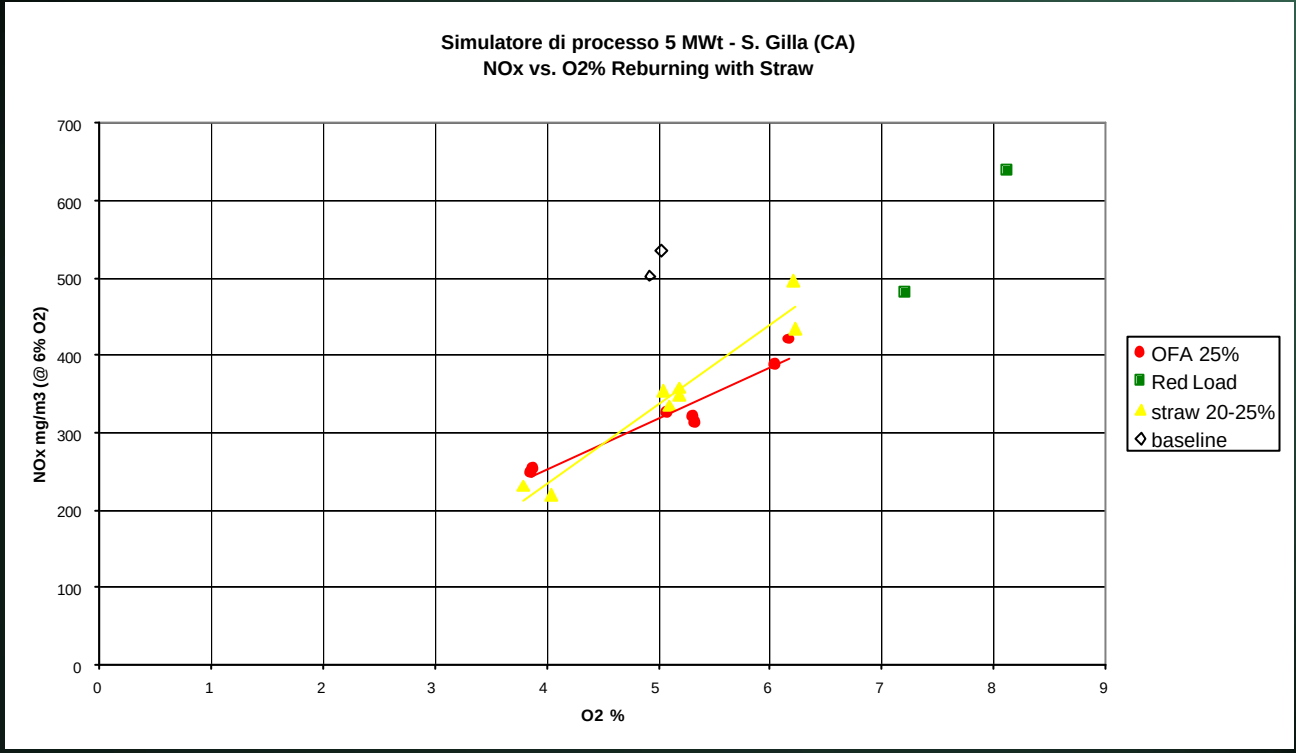
Effect of use of biomass on SO_2

The use of biomass reduces the emissions of SO_2.The curves of SO_2, using wood and straw as secondary fuels give an idea of plant set-up repeatability



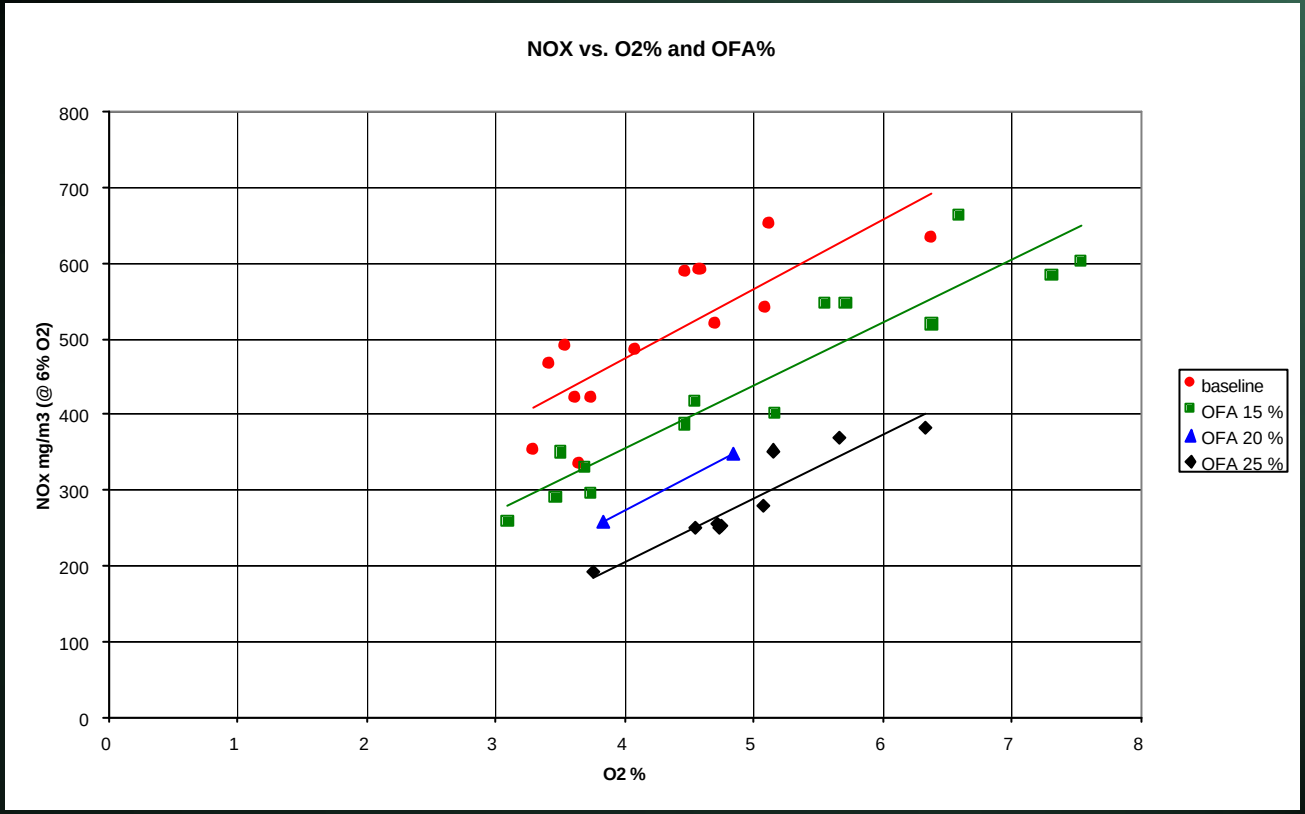
Co-combustion coal straw

25% of OFA lead to a decrease of about 200 mg/m3 NOx
the substitution of about 20% of coal with straw in reburning set-up leads to better results but only at low air excess



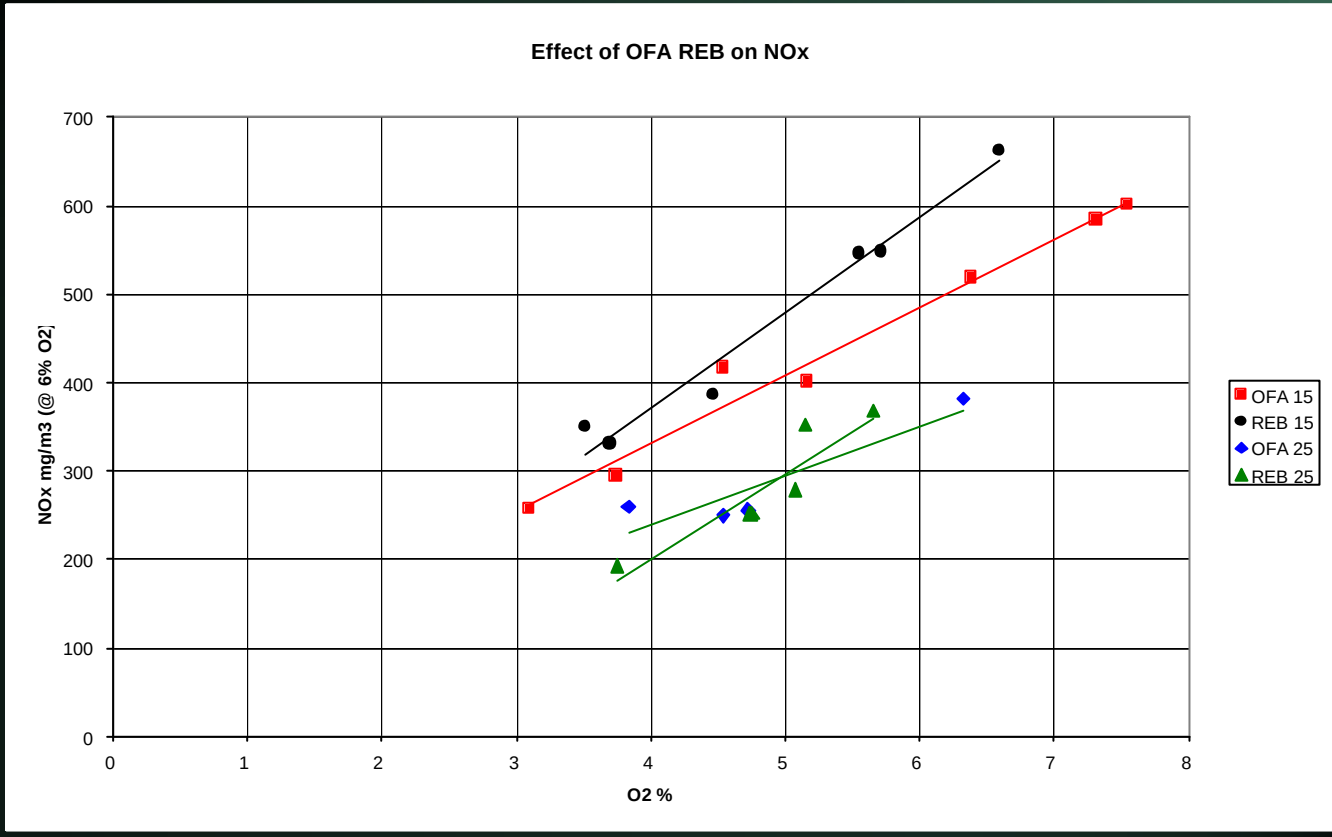
Co-combustion coal-wood

The effect of OFA is a reduction of NOx of about 100 mg/m3 for each 10% increase of OFA



Reburning coal-wood

The reburning set-up with wood leads to a reduction of NOx respect to the OFA set-up only at low excess air and high REB ratio



Combustion behaviour

Using biomass as co-fuel of coal there are the following effects:

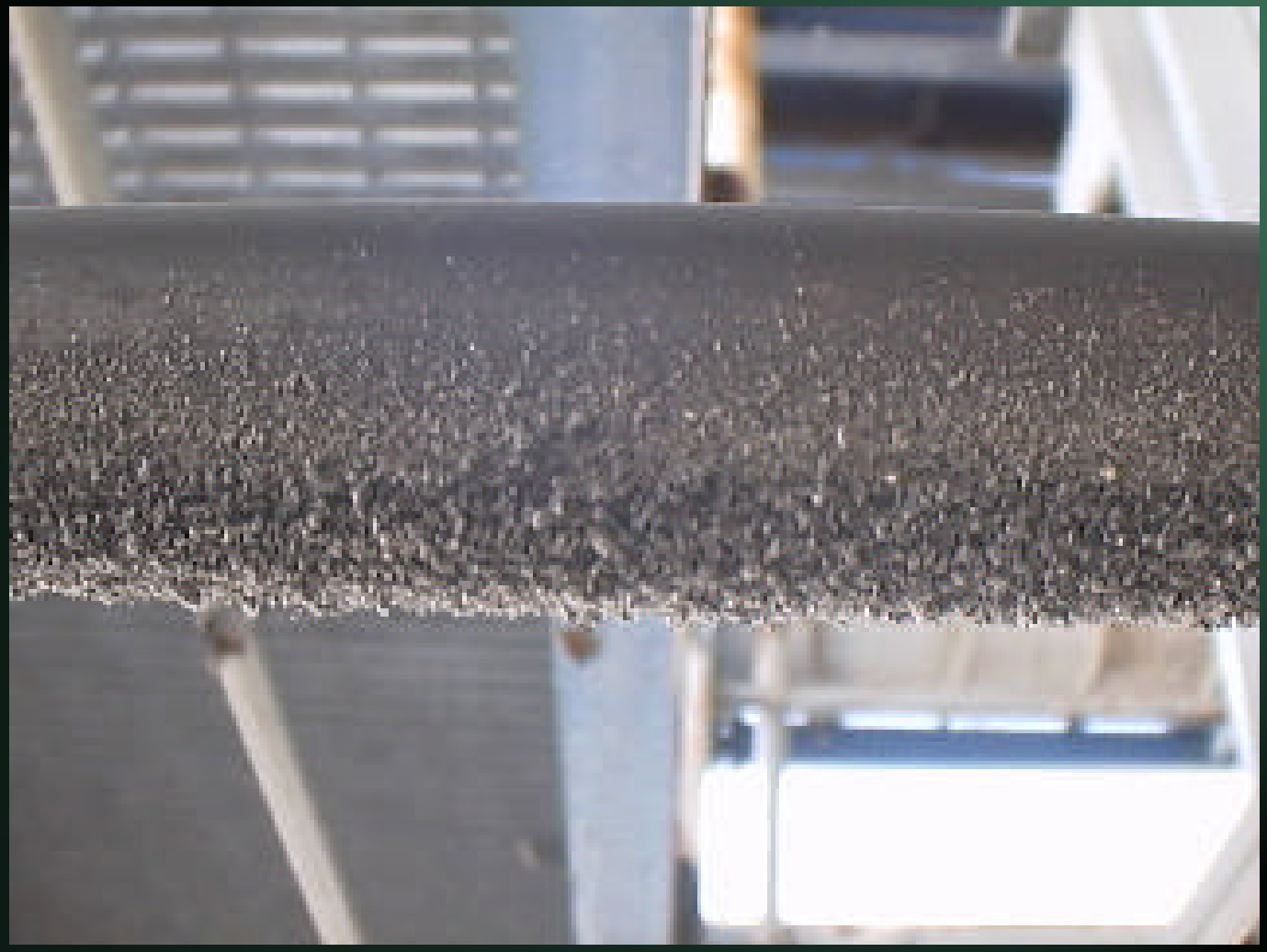
- a reduction of SO2 emissions,
- a reduction of NOx emissions only with wood
- the use of biomass as reburning fuel is possible and at low excess air leads to a reduction of NOx respect to the simple OFA

Deposition during co-combustion

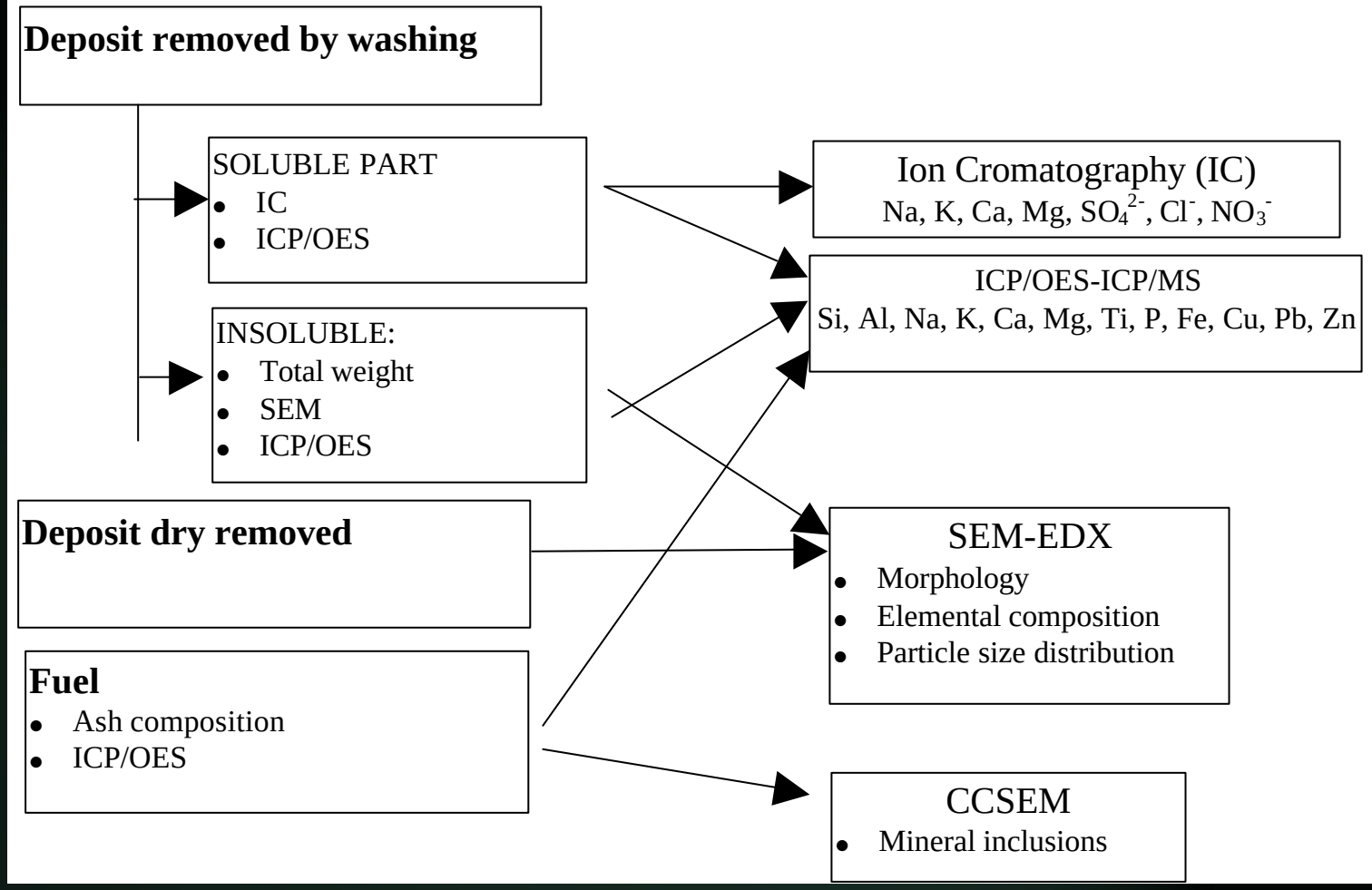
- There are not many evidences of deposition in the practice of a power plant
- You can observe that it is impossible to reach the needed steam temperature
  you have to put more fuel in order to make load
  you have to change some steam cycle parameter
- You can observe the deposits on the banks from the ports and have a visual evidence but it is very difficult to recognise the causes of such effect simply. In general the interaction plant fuel which leads to deposition is complex. This is particularly true during co-combustion

Deposition coal wood

Deposition coal straw



Deposition Index Measurement



Deposition Index Measurement

Two possible ways:

- experimental measurements and empirical fouling tendency evaluation
- physico-chemical modelling of deposition and implementation of such models with thermo-fluidodynamic models

In any case in order to understand deposition it is necessary to give a measure of deposition and to relate this number to the deposit composition and to the fuel composition

Dry deposition (fouling) study assuptions

- The tendency to form deposits of a fly ash depends on the the particles external surface characteristics.

- The compounds which are deposited on the particle surface generated from the evaporation condensation process are soluble in aqueous solutions

- The nature of a deposit can be recognised studying the relationship between the species dissolved by water

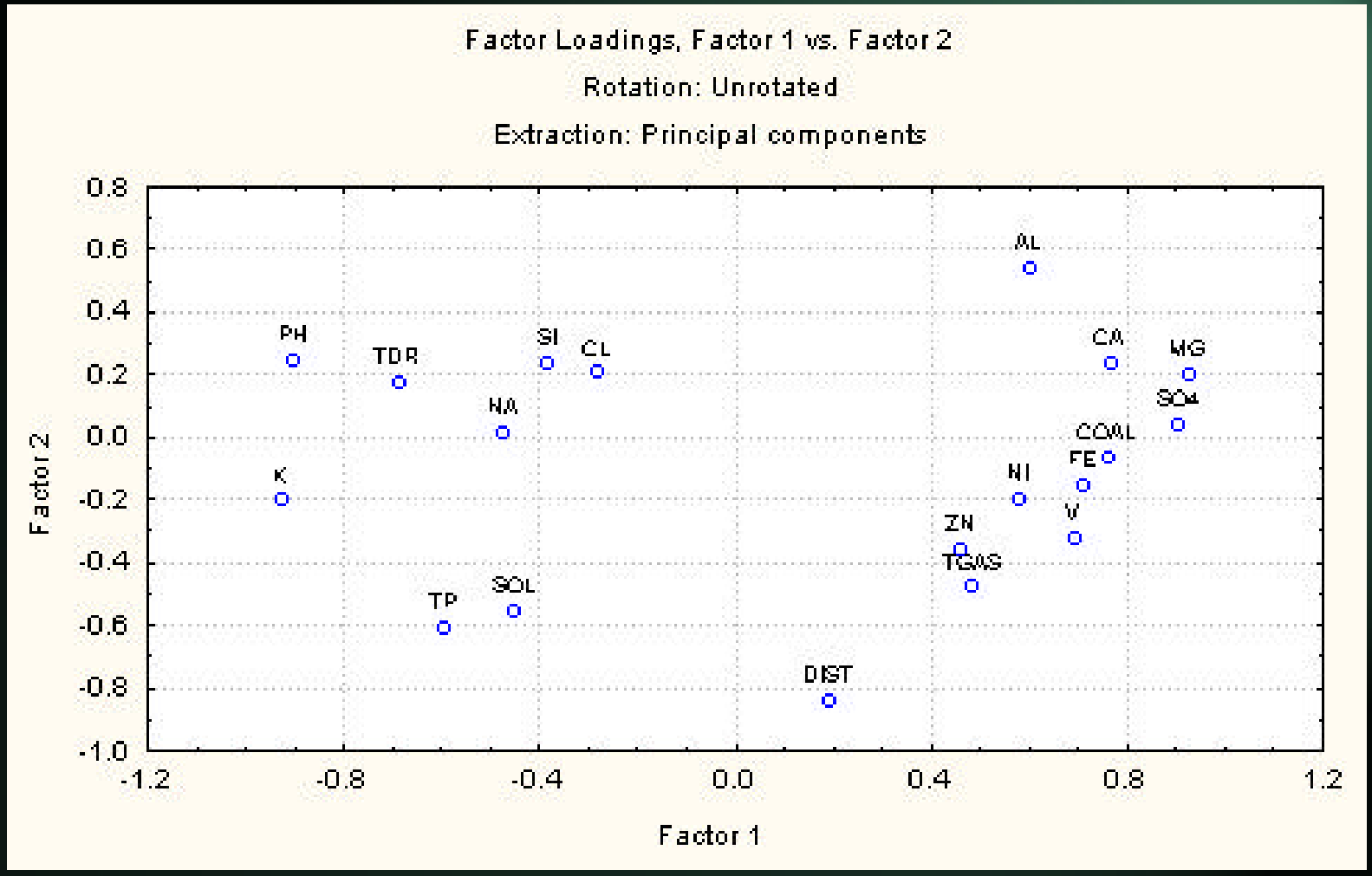
Deposition Index Measurement

- 5 MWth test rig at the S. Gilla, co-combustion tests wood with coal

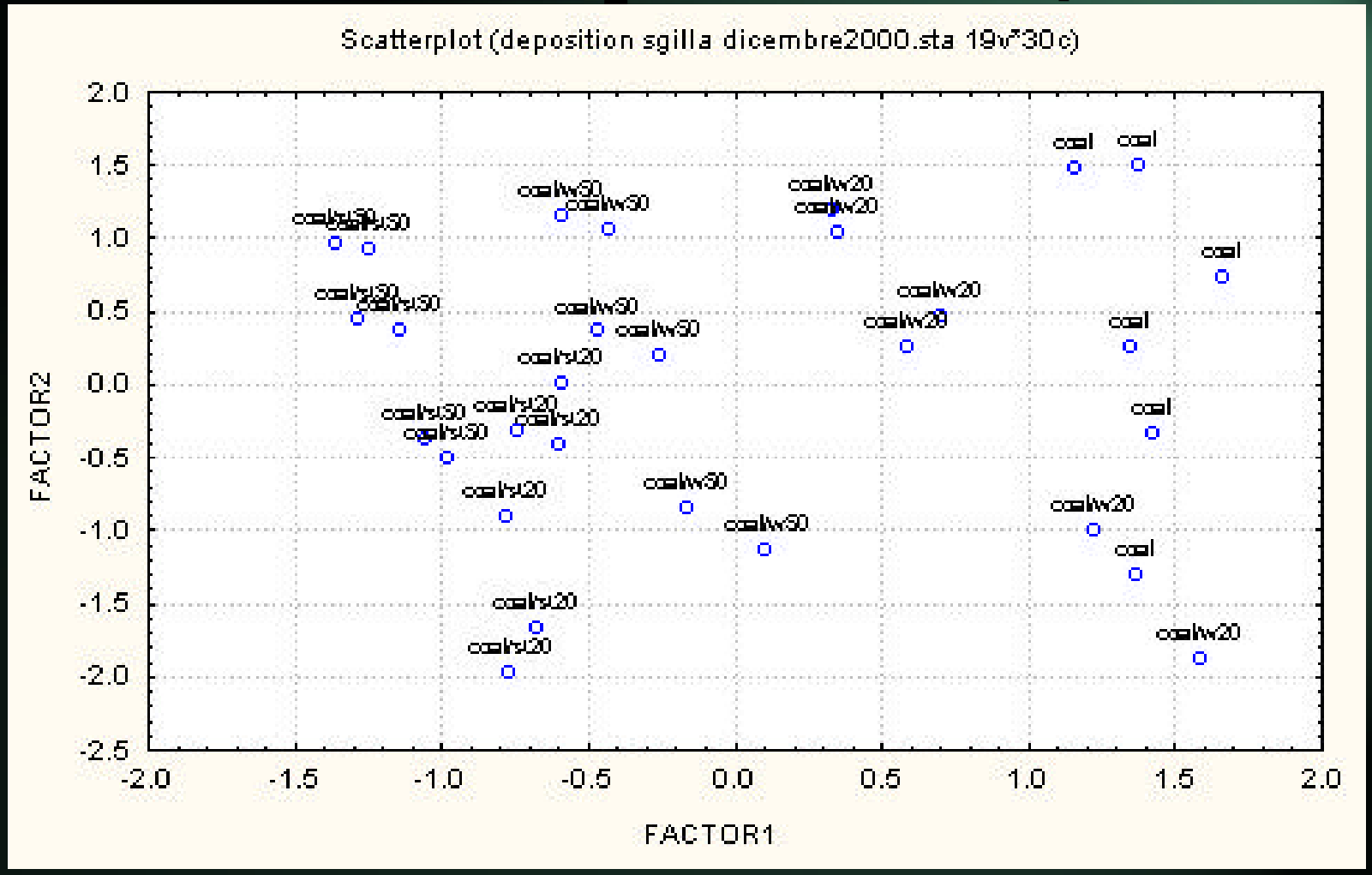
- 5 MWth test rig at the S. Gilla, co-combustion tests straw with coal

- The use of principal components analysis is of great importance in order to understand the mechanisms of deposition

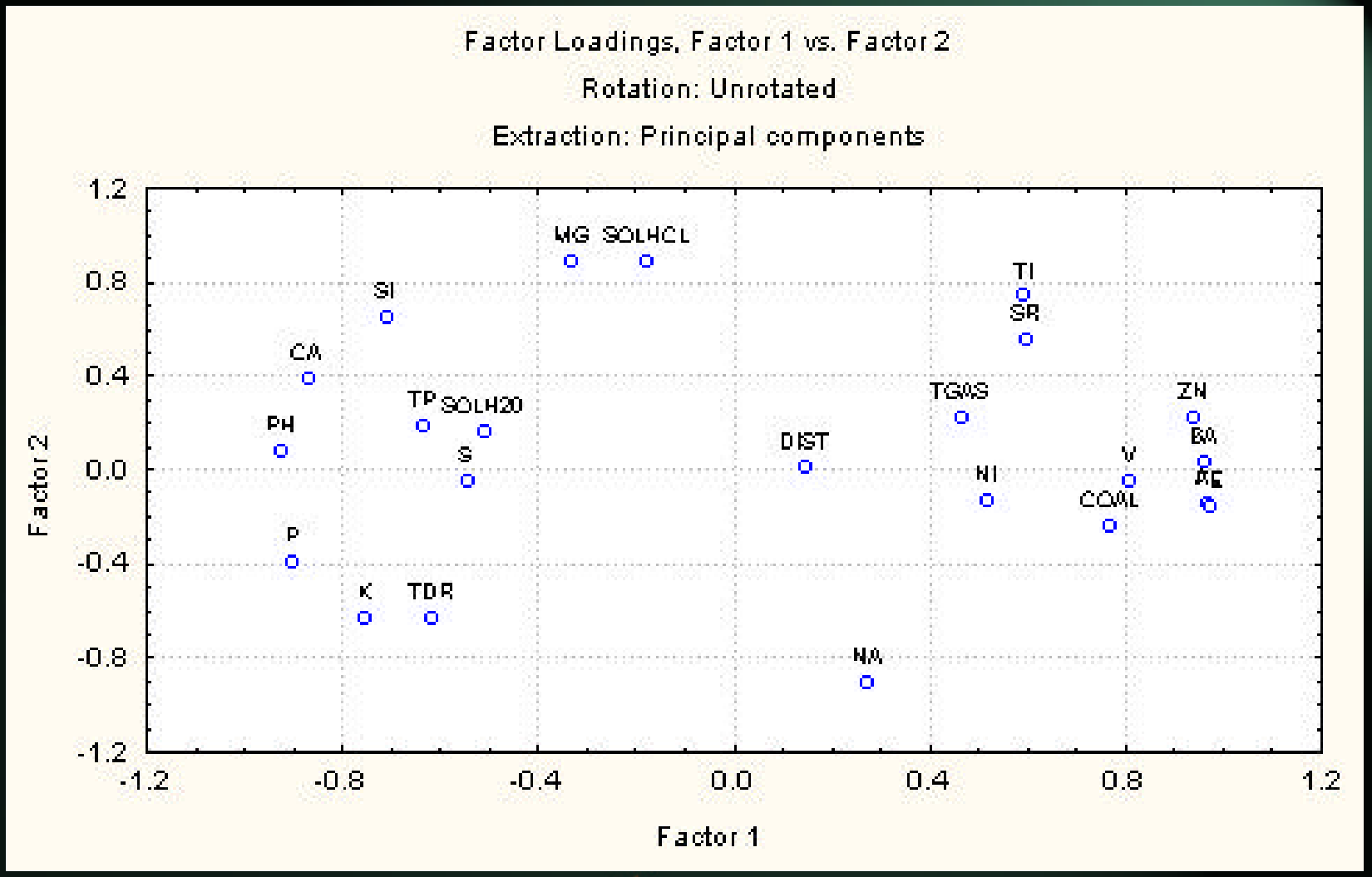
SG coal/biomass H_2O extracts - plot of loadings



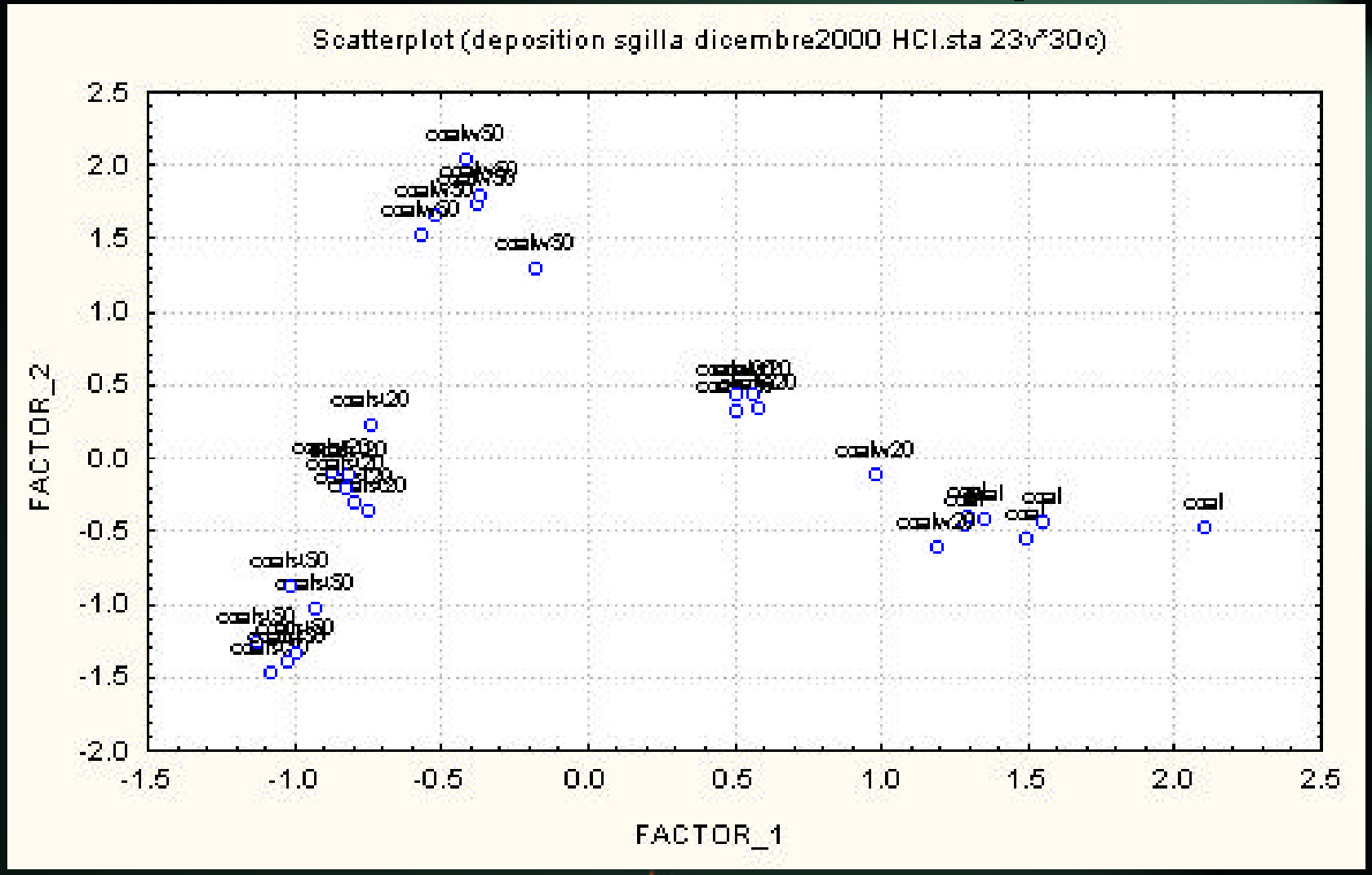
SG coal/biomass H_2O extracts - plot of scores



SG coal/biomass HCl extracts - plot of loadings



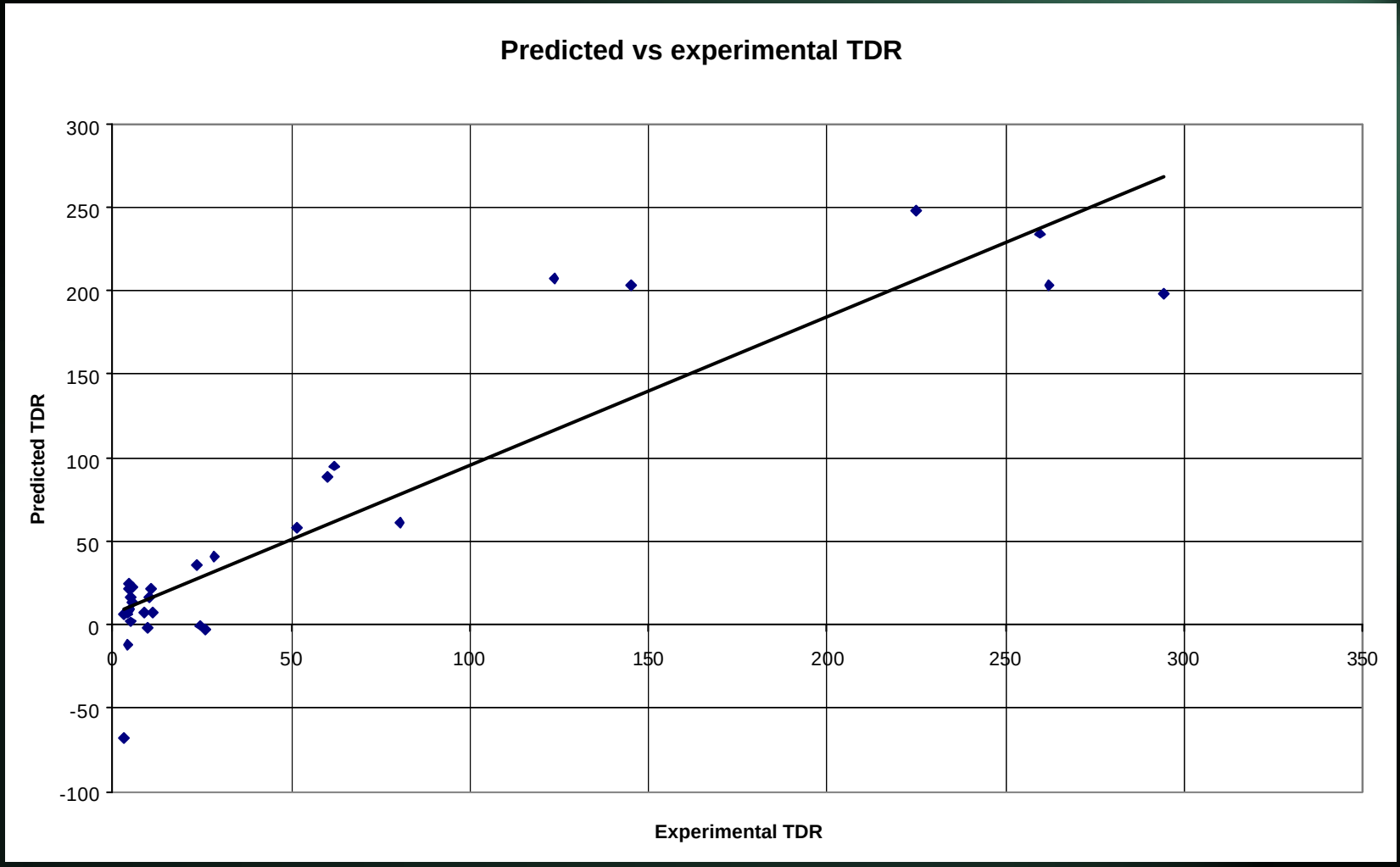
SG coal/biomass HCl extracts - plot of scores



Testing a regression technique
Partial Least Squares

- PLS is a correlation technique which maximises the explained variance and the correlation between the PC and the response (TDR)
- Applying PLS to a matrix where the Xs are the fuel composition dataset and the flue gas and sampling probe temperature with the Y TDR the variance explained in prediction is the 85% of the total variance

TDR Predicted by PLS and Experimental



Comments

The glue of particles is mainly made of calcium and sodium

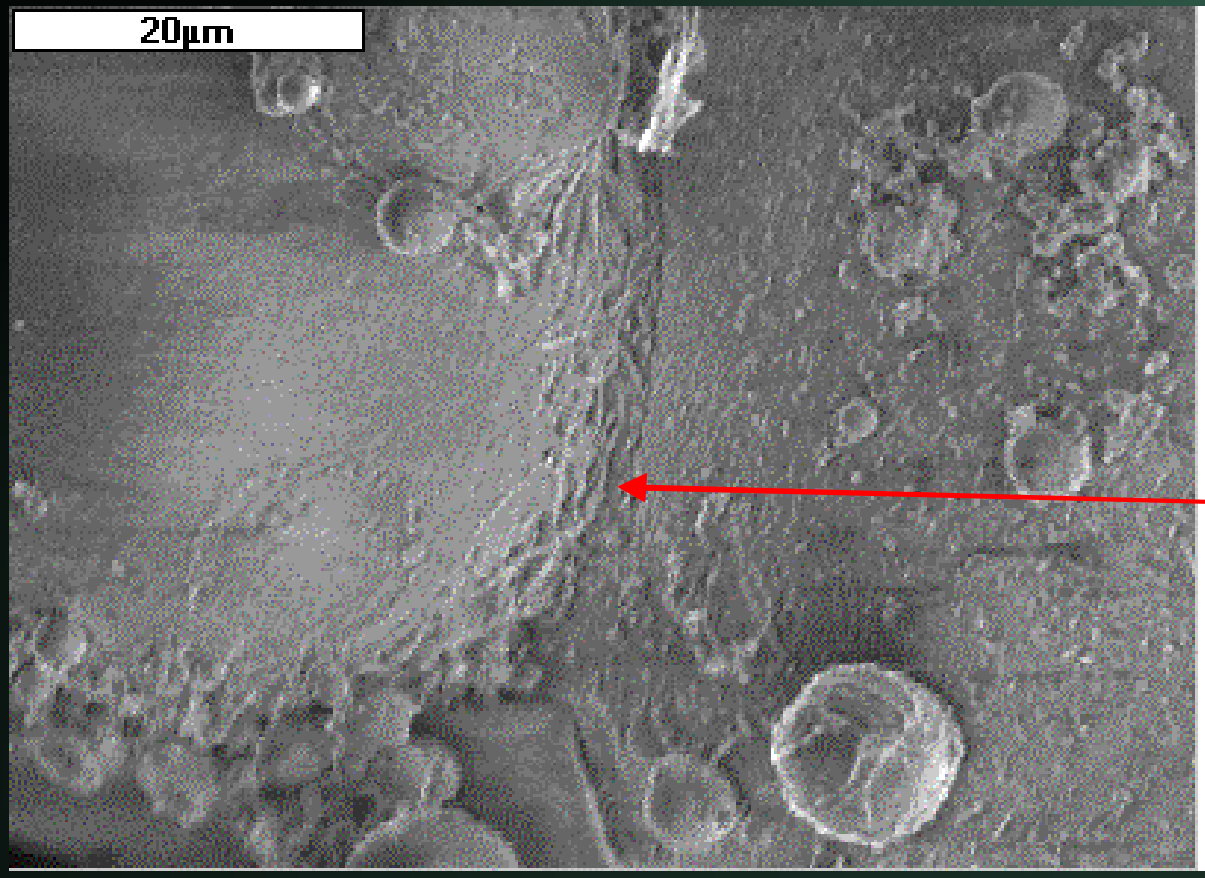
Co-combustion of straw with coal leads to an increase of TDR up to 20-30 times respect to coal

The glue of particles is mainly made of potassium and phosphorus

Comments

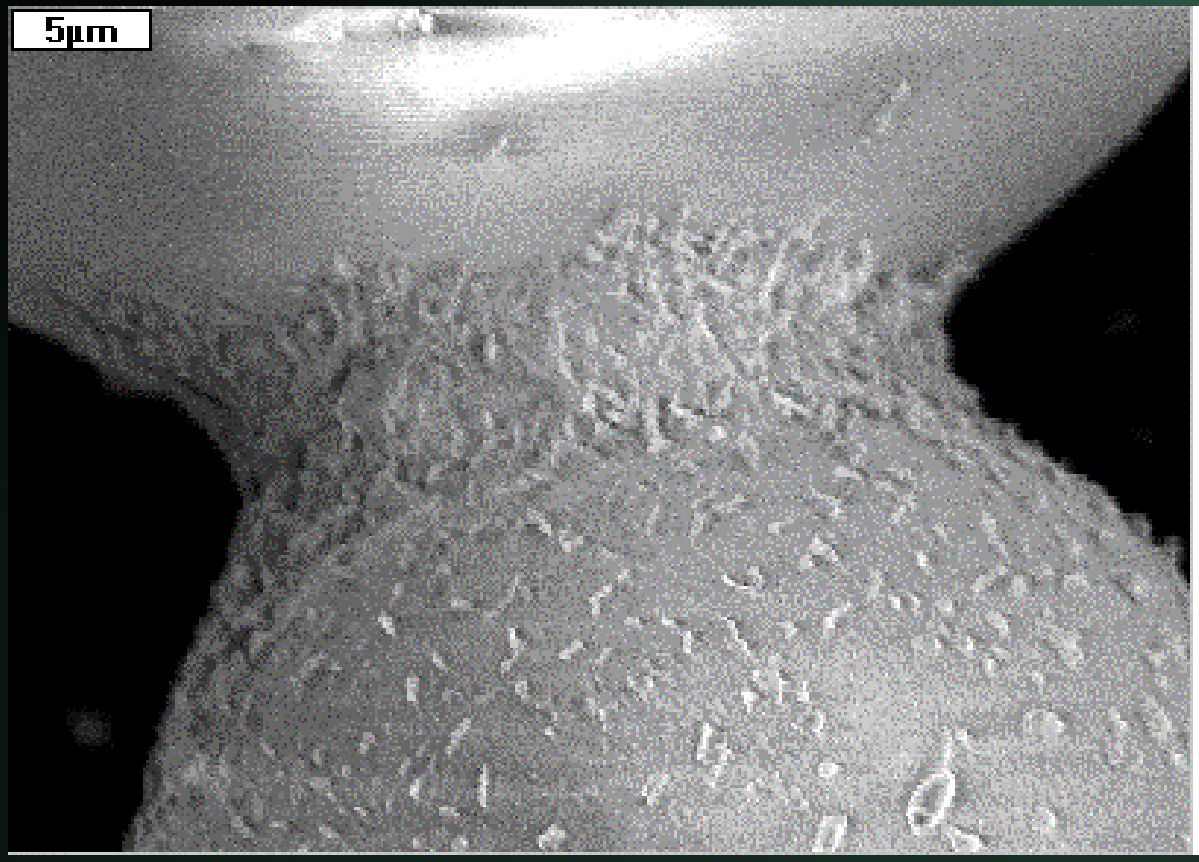
- From Coal tests TDR, water soluble calcium and pH are positively correlated
- Petcoke doesn't lead to an increase of TDR even if an increase of water soluble Vanadium
- Co-combustion of wood with coal leads to an increase of TDR of 2-5 times depending on the plant set-up

Coal wood co-combustion Analysis of glue



Elmt	Element %
Na	1,8
Mg	2,1
Al	6,5
Si	15,4
P	0,2
S	1,2
K	3,9
Ca	25,3
Ti	0,7
Fe	2,3
O	40,6

Coal straw co-combustion Analysis of glue



Elmt	Element %
Na	6,8
Mg	4,5
Al	1,6
Si	10,7
P	8,4
S	2,7
Cl	3,8
K	11,6
Ca	10,6
Ti	0,03
Fe	0,9
O	38,4

Final Remarks

- There are no evidence that exclude the use of biomass as co-fuel in a conventional PF boiler, wood rather than straw
- The problem of cost must take into account also the reduction of emissions when part of the fossil fuels is substituted by renewables
- The application to a full scale plant is necessary in order to evaluate how problems such as stocking, handling, milling can be solved in the practice